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RESEARCH PAPER

Construction and application of an assessment index system for evaluating the eco-community's sustainability

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Abstract: An assessment index system including environment, socio-culture, economy and technology was established for evaluating environmental construction level of community (objective construction), and questionnaire was designed according to paper review for evaluating residential satisfaction (subjective satisfaction). The index system was divided into four layers: system (A), subsystems (B), categories (C), and indicators (D), and in total of 38 indicators was established. The Xihe community, affiliated to Nanfen district, Benxi City, Liaoning Province, China was selected as a case study. Results indicated that the community sustainability index related to objective environmental construction was 0.4355 and was classified as class Ⅲ (moderate); the community sustainability index related to the residential satisfaction was 0.4255, belonging to class Ⅲ. In conclusion, the sustainability of Xihe community was moderate and needed to be improved. Residential satisfaction was lower than objective environmental construction. The assessment index system established in this study is able to reflect the comprehensive sustainability of community and can be used to evaluate other similar communities' sustainability.

Keywords: community sustainability; assessment index system, objective environmental construction; residential satisfaction; Xihe community

Introduction

Under the pressure of environmental degradation and excessive resource utilization, the sustainable development strategy is being widely accepted. Socio-community, as residential environments of humanity, is an important component in the sustainable society. Evolving from normal eco-architectures to eco-communities is an ideal approach for the eco-city development and harmony construction between human beings and nature. Eco-community (also named as green community, sustainable community, eco-housing, etc.), which is actually not a new notion, has its root in sustainable development and community movement (Lachman 1997; Roseland 2000). Eco-community is regarded as an idea to manage settlement development in plan-guided and environmentally friendly patterns (Deakin 2003). The construction of eco-community should aim at reducing the burden of land resources and environment, creating healthy and comfortable living environment, and being harmonious with natural environment (Qin 2006). As an useful approach, community assessment system can be used to measure construction progress, distance to sustainable target, and failures of plans or their implementations (Valentin and Spangenberg 2000; Deakin 2003; Deakin and Allwinkle 2007). The assessment index for eco-community generally includes both objective environmental construction and residential satisfaction (Wu 2001).

However, the existing indicator systems around the world deal little with subjective evaluations (Sustainable Settle 1998; Valentin and Spangenberg 2000; Nicollier et al. 2003; Tian et al. 2007). Most of these sets of indicators concern objective environmental construction, but ignore the public participation, which is very important to community sustainability. Assessment index system without residential satisfaction concerning may bring about much negative effects, such as irrational evaluation etc. A reasonable assessment system should explain the connotation of eco-community better and can be benefit for eco-community construction (Junnila and Horvath 2003).

The overall objective of this study is to establish and apply a comprehensive assessment index system for evaluating the eco-community's sustainability. The specific objectives are: 1) to add questionnaire survey in reflecting residential satisfactory degree; 2) to compare evaluation results between objective environmental construction and residential satisfaction; 3) to discuss

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the application of the comprehensive index system in other regions.

Materials and methods

Study area

The study was conducted at Nanfen district, Benxi City, Liaoning Province. Nanfen district is spatially separate from other regions, with its typical resource–based feature and limited economic development level. Nowadays, the Revitalization Plan for Northeast Old Industrial Base is being implemented here. In order to improve living environment of shantytowns, mass of buildings are being reconstructed. Therefore, tracking community construction progress (including environment, socio-culture, economy and technology) has significant meaning to the regional development. Xihe community, named for its proximity to Xihe River, was selected for the following three reasons: 1) locate in downtown of Nanfen district, which was selected as "Commerce model community" of Liaoning Province in 2006; 2) high usage of library, and the community magazine "Xiao Cao" was established in 2005; 3) high public participation in community affairs and management, such as community volunteers, community patrol and forestation. As a whole, Xihe community plays an important part in the district.

Methods

Environmental construction and residents' satisfaction should be incorporated in evaluating the community sustainability (Li et al. 2005). Evaluation of objective environmental construction was based on an index system established in this study, while residential satisfactory degree was examined based on questionnaires. The two aspects were combined to obtain a comprehensive evaluation system (Fig. 1).

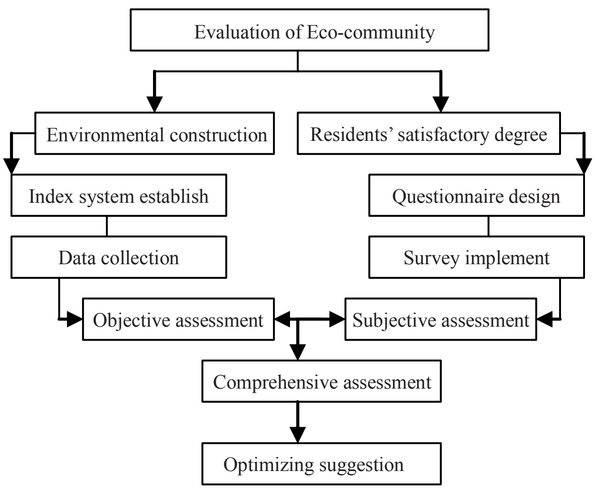

Fig. 1 The technical approach for evaluating community sustainability

Assessment of objective environmental construction

Step1. Selection of indicators

Socio-community is a complicated system and various indicators can be chosen for evaluation. It is unpractical to reflect its sustainability by using too many indicators. Therefore, we tried to establish a synthetical and concise index system in this study. Community condition, data acquirability and maneuverability were considered for indicators selection. The method used by Yuan et al. (2003) was employed to select indicators with assistance of experts. Experts judged each indicator according to the following standards: whether or not the indicators 1) shorten the difference between poor and rich; 2) improve efficient usage of natural resource; 3) create comfortable living environment; 4) attract more residents to settle; 5) promote local economic development; 6) reduce the emission of harmful air. The results were denoted by "agreement, unsure, disagreement", and then quantified by "1, 0, –1", respectively. A system containing 38 indicators was established through this method and the index system was divided into four layers: system (A), subsystems (B), categories (C), and indicators (D) (Table 1).

Step2. Determination weight of indicators

Indicators' weight was determined by the Analytic Hierarchy Progress (AHP) (Saaty 1990) and DELPHI (Shen 2000; HwanSuk and Ercan 2006.) methods. Based on knowledge about assessment, 15 experts in ecology, economy, architecture, urban planning and administration were invited to discuss the weight of each indicator. Judgment matrixes were established. The process was repeated until experts reaching agreement universally (Table 1).

Step3. Standardization of indicators

Indicators were grouped into positive and negative indicators. Standard deviation was used for data standardization:

$$x_i = \begin{cases} 0.5 + \dfrac{x_i - \bar{x}}{10s} & (positive\ indicators) \\ & \qquad (i = 1, 2, ...n) \\ 0.5 - \dfrac{x_i - \bar{x}}{10s} & (negative\ indicators) \end{cases} \tag{1}$$

where x_i is the standard value of indicators, $\bar{x}$ the means of indicators, and s is the standard deviations of indicators.

Step4. Evaluation model

Based on the index system in Table1, the weighted sum of three layers (A-B, B-C, C-D) was computed:

$$Y_j = \sum_{j=1}^{n} w_j x_i \tag{2}$$

where Y_j is the value of one layer (A-B, B-C, C-D), x_i the value of indexes under Y_j, W_i the weight of each indicator, and n is the number of indicators. Then based on existing classification criterion of community sustainability (Wang and Xu 2005; Zhang et al. 2006), a four-grade classification was utilized to classify

community sustainability (Table 2).

Table1. Assessment index system for eco- community

System（A）	Subsystem (B)	Category (C)	Indicator (D)
Community sustainable synthesis index	Environment B1[0.2589]	Artificial environment C1 [0.5812]	Green coverage in the community (D1) [0.3672] Green area per person (D2) [0.3513] Rationality of species allocation (D3) [0.1759] Residential district landscape(D4) [0.1056]
		Natural condition C2 [0.4188]	Quality of water environment (D5) [0.3333] Quality of sound environment (D6) [0.3333] Air quality (D7) [0.3333]
	Socio-culture B2 [0.2291]	Social stability C3 [0.1348]	Employment rate (D8) [0.5] Rate of person enjoy minimum premium (D9) [0.5]
		Culture and education C4 [0.4233]	Percentage of grad from junior college (D10) [0.5] health professional per one thousand (D11) [0.5]
		Social justice C5 [0.1006]	Earning difference per person (D12) [0.3333] Frequency of family violent events (D13) [0.3333] Frequency of maltreat elders (D14) [0.3333]
		Community management C6 [0.2512]	Coverage of safety appliance (D15) [0.3458] Interactive community management (D16) [0.3612] Participation in cultural activities (D17) [0.1542] Usage of public service facilities (D18) [0.1388]
		Population situation C7 [0.0901]	Community population (D19) [0.5] Degree of aged population (D20) [0.5]
	Economy B3[0.2280]	Productivity C8 [0.3333]	Average GDP per person (D21) [1]
		Industry structure C9 [0.3333]	Proportion of third industry production (D22) [0.4] Investment of capital asserts (D23) [0.6]
		Purchasing power C10 [0.3333]	Amount of consumables' retail (D24) [1]
	Technology B4 [0.2840]	Architecture design C11 [0.3333]	Layout (D25) [0.3941] Living area per person (D26) [0.0898] Building structure (D27) [0.0898] Building daylighting (D28) [0.0898] Ventilation condition (D29) [0.0898] Usage of green building materials (D30) [0.1233] Usage of instrumental saving power (D31) [0.1233]
		Traffic design C12 [0.3333]	Path area per person (D32) [0.3333] Whether disjoin pedestrian and vehicle (D33) [0.3333] Distance to the nearest bus station (D34) [0.3333]
		Environment protection C13 [0.3333]	Recycling of rainwater and sewerage water(D35) [0.3211] Usage of green energy (D36) [0.2321] Recycling of rubbish (D37) [0.2347] Popularization of gas usage (D38) [0.2121]

Table 2. Classification criterion of eco-community sustainability

Grade	Value	Qualitative evaluation
I	>0.75	Excellent
II	0.50~0.75	Better
III	0.25~0.50	Moderate
Ⅳ	<0.25	Worse

Assessment of residential satisfaction

Whether being satisfied with community construction or not can be evaluated from social and psychological aspects (Li et al. 2005). Residential satisfaction was evaluated by public participation, promoting communications between residents and urban planners. Evaluation methods included interviews and questionnaire.

Main indicators (including D2, D3, D4, D5, D6 and D7 of environmental subsystem; D8, D10, D15, D16 and D17 of social-cultural subsystem; D21, D22, D23 and D24 of economic subsystem; D25, D30, D32, D32, D35 and D37 of technological subsystem) of each subsystem were selected to design questionnaire (Table 1). Each answer contained seven grades: most dissatisfaction, more dissatisfaction, dissatisfaction, common, satisfaction, more satisfaction, and most satisfaction, which were assigned as 1, 2, 3, 4, 5, 6 and 7, respectively. The evaluation model was as following (Li et al. 2005):

$$S = \left(\sum_{i=1}^{7} i x_i - 1\right) \Big/ 6\sum_{i=1}^{7} x_i \qquad (3)$$

where S is the synthetical sustainable satisfaction index; x_i (i=1, 2, … , 7) is number of people consent from 1 to 7.

Results and discussion

Experts' attitudes toward indicator selection

Public acceptance of artificial environment (C1), natural condi-

tion (C2) and environment protection (C13) was generally high, indicating that the government has made great efforts in propagandizing on environmental protection. The acceptance of population situation (C7) was the secondary high. Experts realized that community scale control was very important. More residents would lead to more energy consumption, waste discharge, which might overload the carrying capacity of land resources. The acceptance of C11 (architecture design) and C12 (traffic design) were the thirdly high. Experts thought layout design before community construction was important. Meanwhile, the acceptance of recycling of rainwater and sewerage (D35) and usage of green energy (D36) were low, the limited economic development level of the community was considered, and the reinvestment of these equipments was too high to bear for Xihe community.

Objective environmental construction

The assessment value of socio-cultural subsystem (B2) was 0.5016 (the highest) and its sustainability was classified as class Ⅱ (better). This indicated the basic condition and development of B2 was quite well, because the community management was good and majority of the residents were with high education level. But B2 would be confronted with depopulation and age structure change in future, many youths left the community for higher education or better jobs and let elders alone. The synthetic index of the community sustainability (A) and the other three subsystems were classified as class Ⅲ (moderate), of which the value of technological subsystem (B4) was the lowest, due to the factor that the community was founded without integrative layout design (Table 3).

Residential satisfaction

Five hundreds and five (505) shares of available questionnaire were collected. Students, officials, teachers and workers showed willingness to participate, but what they care were different. (1) Government officials and teachers care the same. Besides the environment, they pay more attention to chance of participation in community management, education, sanitation and social stabilization, which represent future development potential. They were the only group let the productivity and purchasing power lay behind, for their living condition was good without livelihood worry. (2) Students care more about employment rate and industry structure. They have tasted the competitive pressure absolutely. Differing from the elders, they care more about the living quality. Meanwhile, they are short of understanding present economic level and think community must be fixed with devices of reusing rainwater and sewerage water. (3) Workers care more about purchasing power and employment rate, which these indicators were used to weight the development state. Most of interviewers (55%) were within the age from 21 to 55. This group of people was mostly in charge of community affairs and their effort to community affairs was high. People above the age of 60 generally refused to participate. Probable reason was that they thought they were too old to participate in community affairs.

Table3. Result of evaluation on objective environmental construction at Xihe community

System (A)	A 0.4355 (III)												
Subsystem (B)	B1 0.4143 III				B2 0.5016 II				B3 0.4689 III			B4 0.3751 III	
Category (C)	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
	0.4812	0.3214	0.5417	0.4813	0.3211	0.6512	0.3215	0.4578	0.4877	0.4612	0.4032	0.4322	0.2899
	III	III	II	III	III	II	III	III	III	III	III	III	III

All the reviewers thought the community development was better than before. Evaluation of residents' satisfactory degree was shown in Table 4. The value of socio-cultural subsystem (B2) was 0.5003 (the highest) and its sustainability was classified as class Ⅱ (better). The synthetic index of the community sustainability (A) and the rest of three subsystems were classified as class Ⅲ (moderate), of which the value of technological subsystem (B4) was the lowest (Table 4).

Table4. Result of residential satisfaction to community construction in Xihe community

System	Residents' attitude							Score	Grade
	Most satisfy	more satisfy	satisfy	common	dissatisfy	More dissatisfy	most dissatisfy		
B1	12	92	320	758	1398	420	30	0.4016	III
B2	9	382	433	1326	570	282	28	0.5003	II
B3	16	205	421	1053	895	431	9	0.4502	III
B4	8	35	286	285	2156	153	107	0.3678	III
A	—	—	—	—	—	—	—	0.4257	III

Moreover, majority of the residents were critical to the architecture design (C11) and traffic design (C12). Meanwhile, the satisfactory degree of green coverage (D1) was high, but the species allocation (D3) was unreasonable low. The results indicated that planners should make greater efforts in community plan, residents should take more enthusiasms in participating community construction, and ecological engineering technique should be flexibly used in community construction.

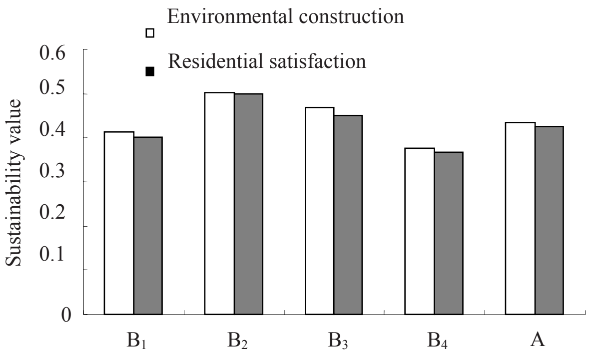

Fig. 2 Comparison between objective environmental construction and residential satisfaction at Xihe community. B1, Environmental subsystem; B2, Sociocultural subsystem; B3, Economic subsystem; B4, Technological subsystem; A, Sustainable synthetic index

Overall results showed that residents' satisfactory degree was lower than objective environmental construction. The synthetic index of sustainability (A) was below 0.6, indicating that Xihe community was still away from eco-community and more work should be done in community construction (Fig. 2).

Conclusions

Through questionnaire and interviews, residents could know their community well, and their enthusiasm in building homestead was encouraged. Meanwhile, they could add to understanding of community development and management. Acceptance for community sustainability was related with many social and mental factors. Only improvement in the objective environmental construction could not result in an increasing of residential satisfaction. The combination of environmental construction effects and residential satisfaction should be considered in attempting to make comprehensive evaluation decision. The community sustainability can be deduced from comparing the assessment index with other communities'. Meanwhile, it can be used to guide future development of community. However, the assessment index system has limitations for different regions have distinct community behaviors. Moreover, there was duplication between indicators (such as D31 and D35). Statistical method suggested that universal and normative indicator system is still prevented to be proposed.

Due to data's acquirability, only current condition of community was considered in this study. It will be better to add dynamic transformation of community construction. However, it needs to make more efforts in the data collection and questionnaire design.

Eco-community is an ideal state, and it will change with human's understanding. Therefore, related evaluation standards should also be change with time.

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